A.D. 1858, *20th February.* N° 329.

Electric Telegraphs.

LETTERS PATENT to William Thomson, Doctor of Laws, Professor of Natural Philosophy in the University and College of Glasgow, in the County of Lanark, for the Invention of "Improvements in Testing and Working Electric Telegraphs."

Sealed the 23rd April 1858, and dated the 20th February 1858.

PROVISIONAL SPECIFICATION left by the said William Thomson at the Office of the Commissioners of Patents, with his Petition, on the 20th February 1858.

I, William Thomson, Doctor of Laws, Professor of Natural Philosophy in the University and College of Glasgow, in the County of Lanark, do hereby declare the nature of the said Invention for "Improvements in Testing and Working Electric Telegraphs," to be as follows; and, for the sake of distinctness, I have divided the description of the nature of the said Invention into several parts, that is to say:—

Part First.—I propose to test the insulation of a telegraphic wire by communicating a charge of electricity to it, and then leaving it with both ends insulated, and some part of it connected by a conductor with an instrument for indicating electro-static potential. I propose to use any suitable electroscope or electrometer for that purpose, but I prefer an instrument consisting of the following parts:—(1), a testing conductor turned to a true figure of revolution, and divided into sectors, any or all of which may be insulated from the ground and from one another; (2), an index moveable

round the axis of this solid, and which may or may not be guarded from every other kind of motion; (3), a conductor connecting that index with a body kept electrified to an approximately constant potential, but not occasioning any inconvenient impediment to the motion of the index; (4), conductors to connect one or more of the parts of the testing conductor with the telegraphic conductor to be tested, and one or more of them with the earth; (5), a case or cases, with an atmosphere artificially dried, to preserve the moveable index from disturbances by currents of air or otherwise, and to maintain good insulation in the various parts in which insulation is required; (6), a graduated scale or other arrangement for allowing the position of the moveable index to be recorded at any time; (7) a guage for testing the potential in the body mentioned in article (3), which may consist of any electrometer or electroscope whose indications depend on one independent variable, namely, the potential to be tested. I prefer an instrument answering to the following description:— A conductor turned to a true figure of revolution, or nearly so, to be connected with the conductor whose potential is to be tested, or with the earth and a moveable and fixed, or two moveable bodies capable of diverging from one another round the axis of that figure, and maintained at the earth's potential, or else to be connected with the conductor to be tested. This instrument may, if constructed so as to have sufficient sensibility, or if a sufficiently high initial electrification is given to the telegraphic wire to be tested, be also advantageously used directly to test the insulation of the telegraphic wire.

Second Part.—I propose also to test the insulation of a telegraphic wire by making experiments in various ways, so as to compare the freedom which the defects of insulation allow to electricity passing from the telegraph wire to the earth when any parts or part of it is put in communication with a source of electricity with the freedom which is afforded by a standard wire or other conductor for electricity to pass along itself. One of the ways in which I propose to carry out this is to apply a powerful battery to send a current through the standard conductor into the telegraph wire, and then to apply the electrodes of a tangent or other galvanometer, or of an electrometer or electroscope, such as either of those described, or of any other kind, successively to the two ends of the standard conductor, and to one end of the same and the earth.

Third Part.—I propose to test a submarine telegraph conductor during the operation of laying it, by regularly measuring the strength of currents produced in it by the electro-motive force of a constant battery or batteries, and that by means of various forms of galvanometer which I have invented for the special purpose of being used at sea. The chief peculiarity of the different

kinds of marine galvanometer which I have invented consists in the moveable magnet, or moveable indicating body, being supported by means of one, two, three, or more threads, wires, or fibres in such a manner as to allow it the requisite degree of freedom to move, and to give it the requisite degree or stability independently of gravity and terrestrial magnetism, and in such a manner as to be only slightly disturbed by these forces and the reaction of its own inertia against the inequalities of the ship's motion. The apparatus which I prefer for testing at any time the position of the body which indicates the strength of the current by its motion is a mirror attached to this body, and used either to reflect light after or before or after, and before passing through one or more lenses, so as to be sent to different parts of a graduated screen when the moveable body is in different positions.

Fourth Part.—I propose to use a double bifilar suspension for the magnet or other moveable indicating body in a galvanometer, or in a relay, or in any instrument used for testing or for working electric telegraphs which I have invented, to give any requisite degree of stability or of instability to the mean position of equilibrium or balance.

Fifth Part.—I propose to use ordinary modes of suspension, also such as bifilar or single suspension by silk or other fibre or wire, for the moveable indicating body, in telegraphic instruments. When any one of the supporting or guiding wires or filaments in any of these arrangements, or in the double bifilar method, is of conducting substance and of sufficient conductivity, and when it is desired to make or break an electric circuit or electric circuits by the motions of the said moveable indicating body, I propose to use that wire or filament or those wires or filaments for bringing into that circuit or those circuits a piece or pieces of platinum or other metal touching a metal stop, or detached from the same, according as the moveable body is on one side or the other of its mean position, or any other suitable arrangement for making & breaking circuit. When none of the suspending or directing filaments are of conducting material, and when it is desired to have a circuit or circuits made or broken, I propose to use a vessel containing a conducting liquid, and a conductor connected with the moveable body dipping into it to maintain the unbroken part of the electric communication between the moveable and fixed parts of the circuit or circuits.

Sixth Part.—When electro-motive forces of different positive and negative strengths are used to give varied signals in actual telegraphing, and when it is convenient to use a relay for transmitting the same system of signals over any station by the aid of a local battery, or otherwise, I propose to use a coil or

a number of different coils, each with one or more moveable magnets in its neighbourhood, so acted upon by the elastic force of filaments or the deflecting action of fixed magnets that one set of them will not move when the current is in one direction, and that one or more of the same set will move when the current is in the contrary direction, according as the strength of the current is less or more, and so for the other sets of moveable magnets when the current is in the contrary direction. When any one of these magnets moves it breaks or makes, or breaks and makes electric communication in a local circuit or circuits, so as to cause the corresponding degree of electro-motive force to be applied to the part of the telegraph line along which the electric signals are to be forwarded. The same instrument, which may be called a galvanometric relay, may be used for receiving and recording the message marking the motions of the different moveable magnets by any suitable method.

Seventh Part.—I have also invented another kind of galvanometric relay or receiving instrument, in which by a single chief moveable magnet or two magnets, each of which can only leave its mean position in one direction, two or more magnets, moveable about fixed axes, are turned from their positions of rest, and so caused to make or break circuits for local batteries or other electrometers, according as the chief moveable magnet moves through a less or a greater arc when deflected from its mean position. I propose to use this instrument, either as a receiving and recording instrument, or in any operation connected with the manufacture or use of electric telegraphs, for which it is suited.

Eighth Part.—I propose also to use the electroscopes described above, or any other electroscope or electrometer, giving indications by electro-static force as a receiving instrument, or an instrument to be used in making comparisons of clocks, or in giving time or for any other purpose connected with the manufacture or use of electric telegraphs worked otherwise than by frictional electricity for which it is suited. I prefer for this purpose the electroscope first described above.

Ninth Part.—I propose also to use thermal effects produced by radiant heat reflected from a mirror or reflecting surface of any kind attached to the moveable indicator of a receiving instrument for the purpose of having the indications recorded. The thermal effects which I propose to use thus may be either the melting of wax or of any other fusible substance, or any chemical or other change produced in the quality or appearance of any substance by heat or thermo-electric effects in local circuits excited by the radiant heat. The last-mentioned kind of effects may be used in the construction of a

third kind of galvanometric relay, in which one, two, or more thermo-electric circuits will be excited, according to the distance and the direction of any excursion of the beam of reflected radiant heat, and will produce motions in moveable magnets, by which the electric currents to do the work wanted may be checked and permitted to pass, as required.

Tenth Part.—I propose to use photography for recording electric signals, as indicated by motions of a moveable body or moveable bodies, either by light reflected from a mirror attached to the moveable body or transmitted by an aperture or transparent part in the moving body, or by influences of a shadow or image of the moving body or of the shadow or image of any part of it.

Eleventh Part.—I propose to use a relay, by which messages shall be transmitted simultaneously from two or more submarine cables into a smaller number of land wires, or a smaller number of submarine wires of shorter length, or the converse, or generally in any case when it is desired to transmit messages from one wire or a number of wires into and along a different number of wires.

The system by which I propose to do this is sufficiently explained by the plan I would follow in using two or three submarine lines in connection with one shorter submarine line, or one land line, which is as follows:—Each singly read or recorded indication from each of the long submarine lines would by any kind of relay that might be convenient make an electric signal, single or compound, indicating the degree of intelligence derivable from it alone, and these secondary electric signals would be made at equal intervals of time from one another and in general alternately (or in order of succession) as they come from the submarine lines. When it can be arranged that the submarine lines are to be worked at the remote end, so as to send signals at equal intervals of time in recurring order one after the other, the kind of relay which will be required will be merely one in which signals from two different submarine lines are forwarded indifferently at the instant as they come. When this cannot be so arranged, a mechanical arrangement must be made in the relay to keep back signals which have come in too soon from any of the submarine lines, and to transmit all that come in the regular order of their arrival.

Twelfth Part.—I propose to use electric sparks excited by a Ruhenkorff coil, or any other convenient instrument, and passing between any part of the moveable body indicating electric signals and a sheet of matter fixed or carried along by a regular motion near, it to record by impressions, chemical changes, or perforations produced by these sparks, the motions of the moveable body; or to use electric currents sent through a conducting liquid covering part of the

moveable body, so as to make impressions, chemical or other, on a sheet also covered by the liquid. In using electric sparks to record the indications of a moveable body in a galvanometer or galvanometric relay employed for telegraphic purposes, I propose to have a regular succession of sparks following one another at equal intervals of time, each making a mark on the paper or other sheet receiving the impression or perforation.

Thirteenth Part.—I propose, when convenient or desirable for any purpose, to use an apparatus by means of which electric signals may be read off by observing the degrees, greater or less, of motion of a moveable body directly; or by observing a spot of light reflected from a mirror carried by the moveable body and thrown on a graduated screen.

Fourteenth Part.—I propose, in long lines of submarine telegraphs, to use apparatus by which, for a single signal, an electric current of a stated strength is as rapidly instituted in a telegraph wire as possible, and maintained as nearly as possible at the stated strength until an indication is taken from it by any of the receiving instruments, galvanometers, relays, electroscopes, or electrometers, described above, or by any other which may be convenient. The indication must be of such a kind that from it, with due allowance for the electric condition of the wire as effected by previous operations, it may be possible to estimate what was the strength of current arranged for at the remote end. According to the strength of current (positive or negative) thus investigated, one number or another, one letter or another, one word or another, one piece of intelligence or another, is read off according to a prearranged code. I should use a Daniell's or other constant battery, or any other electrometer by which definite and sufficiently exact measures of electromotive force can be applied for making electric signals of this kind. I propose to use the following plan for making the current as rapidly as possible approach the stated strength for any signal, and that whatsoever may have been the strength employed in the signal immediately preceding it, or for any of the preceding signals:—When commencing with the wire unelectrified, a stronger electro-motive force than that required to maintain the current at the stated strength is first to be applied for a short time, and after that, the electromotive force just required to maintain a current at the stated strength is applied and continued until the time comes to make the next signal. An electro-motive force, differing (positively or negatively) from this one by a greater amount than that by which the electro-motive force corresponding to the new signal differs from it, is next applied for a short time, after which the electro-motive force simply required to maintain the stated strength corresponding to the new signal is applied, and held on until it is time to commence

a third signal, and so on. I propose, also, in some cases to use the following plan :—To apply constant battery power during a certain measured interval of time, then another constant battery power during another equal interval of time, and so on; these degrees of power being each determined by calculation or otherwise, so as to compensate, so far as is required, the residual effects of preceding operations, and at the same time to produce a new effect constituting or contributing towards a new signal.

Fifteenth Part.—When it is desired to work through a submarine line or through a very long air line in both directions at once, I propose to keep the coil, coils, or conductor of the galvanometer relay or other instrument used for receiving signals in electric operation in connection with the telegraphic line, only during certain intervals of time, not constantly; and I propose to do this also, when it is convenient to do so for any reason whatever, whether when working in both directions at once or not. By this means, I propose to eliminate, from a galvanometer or other instrument used for receiving signals at the same end as that from which signals are being sent, the comparatively violent action which is experienced in the part of a telegraph conductor next the end from which a message is being transmitted, or in wires between it and the earth, during rapid changes of its electric potential.

Sixteenth Part.—I propose either to compensate or to allow for the residual effects experienced from preceding signals, so that the indications of the receiving instrument in use may be either not sensibly affected by them, or that the indications it would have given had it not been affected by them may be estimated.

Seventeenth Part.—In working in both directions at once, I propose to make the beginning of each electric signal as nearly as possible simultaneously at the two ends or alternately at definite intervals of time; and to do the like with every change of battery, application, orof electro-motive force or potential; and for that purpose I use a mechanical apparatus at each end, regulated according to a clock, or mechanically by clockwork; and I propose to have electric comparisons of time between the two ends made as frequently as is necessary to make these two mechanisms keep time with one another as accurately as is required.

Eighteenth Part.—I propose to use, when convenient or when desired for any object, two or more different galvanometers or other receiving instruments, either each self-recording, or each read off by one or more observers, or all read off by one observer but thrown into electric operation in connection with the telegraph wire during intervals regulated by the same mechanism for keeping time as that which is used in making the signals.

Nineteenth Part.—For checking the motion of any moveable indicator in a receiving instrument after its indication has been read off, I propose to use a magnet moved by mechanism or a vessel of liquid brought up so as to cover part of the moveable body, and removed again, if necessary, when a new indication is to be taken, or by turning or otherwise moving the filaments or wires by which the body is supported, when it is so supported, or by other suitable methods.

Twentieth Part.—For increasing, diminishing, or regulating, to any desired degree, the stability of the moveable body of a galvanometer or galvanometric relay, or of any moveable body, part of which is a magnet or an electro-magnet, or a body in any way under the influence of magnetic force, I propose to use either fixed steel magnets, or a fixed electro-magnet, or wires conveying currents of electricity, either in conjunction with any of the modes of suspension described above or when the moveable body is supported in any other way.

Twenty-first Part.—In the use of galvanometers or galvanometric relays, or of any other kind of relay or receiving instrument, I propose, in order to compensate the effect of electrification of the telegraph wire remaining over from previous signals, to use in the neighbourhood of the moveable indicating body an electro-magnet or coil of wire conveying a current instituted and regulated to produce the desired effect, or a steel or other magnet moved so as to produce the desired effect. When it is not convenient to make allowance for such residual effects from previous signals by calcuation or otherwise, and when they are of such an amount as to exercise a sensible disturbance if not compensated, I propose to use similar apparatus under similar conditions in sending messages through either a land or a submarine line in both directions at once, for the purpose of compensating the effect on any receiving instrument due to signals transmitted in the direction contrary to that from which the signals to receive which it is employed are coming.

Twenty-second Part.—I propose to use two mirrors attached to the moveable bodies of two galvanometers to be excited by currents from two separate lines, and I propose to transmit light so as to be reflected from these two mirrors successively and thrown on a screen, so as to give a visible effect, or by photographic or thermal influence, a recorded effect, by which any lines, figures, letters, or symbols drawn or written at one station upon an instrument adapted to give different degrees of electro-motive force to the two lines according to the two independent variables thus dealt with, may be written, drawn, or made visible at another station. For transmitting a line drawing or writing of any kind by telegraph, I propose to add a third wire, which will

be so connected & arranged, that when the tracing point is lifted from the surface on which the curve is drawn at the one station, the indicating or marking beam of light will be cut off at the other station.

SPECIFICATION in pursuance of the conditions of the Letters Patent, filed by the said William Thomson in the Great Seal Patent Office on the 19th August 1858.

TO ALL TO WHOM THESE PRESENTS SHALL COME, I, William Thomson, Doctor of Laws, Professor of Natural Philosophy in the University and College of Glasgow, in the County of Lanark, send greeting.

WHEREAS Her most Excellent Majesty Queen Victoria, by Her Letters Patent, bearing date the Twentieth day of February, in the year of our Lord One thousand eight hundred and fifty-eight, in the twenty-first year of Her reign, did, for Herself, Her heirs and successors, give and grant unto me, the said William Thomson, Her special licence that I, the said William Thomson, my executors, administrators, and assigns, or such others as I, the said William Thomson, my executors, administrators, and assigns, should at any time agree with, and no others, from time to time and at all times thereafter during the term therein expressed, should and lawfully might make, use, exercise, and vend, within the United Kingdom of Great Britain and Ireland, the Channel Islands, and Isle of Man, an Invention for "Improvements in Testing and Working Electric Telegraphs," upon the condition (amongst others) that I, the said William Thomson, my executors or administrators, by an instrument in writing under my, or their, or one of their hands and seals, should particularly describe and ascertain the nature of the said Invention, and in what manner the same was to be performed, and cause the same to be filed in the Great Seal Patent Office within six calendar months next and immediately after the date of the said Letters Patent.

NOW KNOW YE, that I, the said William Thomson, do hereby declare the nature of my said Invention, and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement (reference being had to the Drawings annexed) that is to say:—

For the sake of distinctness I have divided the description of the said Invention into several parts, that is to say,—

Part First,—I test the insulation of a telegraphic wire by communicating a

charge of electricity to it, and then leaving it with both ends insulated, and some part of it connected (and when I use the term "connected" here and throughout the Specification, I mean, unless otherwise expressed, connected by a wire or other conductor of electricity,) with an instrument for measuring electrostatic potential, and leaving it so connected, and observing the diminution of its potential in a certain time. "Potential" is a term the mathematical definition of which is well known to all persons conversant with the mathematical theories of electricity, magnetism, and attracting forces generally; for the present purpose it is sufficient to say, that the "electrostatic potential," or, as I shall call it for shortness simply the "potential," for any point A in space is a quantity depending on the position and electrical state of all the bodies which act at the point A (being in strictness all the bodies in the universe, but with sufficient accuracy for the present purpose all the electrified bodies in the neighbourhood of A), and such that the difference between the values of the potential at the point A, and the potential at any other point. B is a measure of the tendency of electricity to flow from A to B, or vice versa, supposing A and B connected by a small conducting wire. It follows from this, that where there is equilibrium, the potential at every point of an electrified insulated conducting body, including every other insulated conducting body connected with the first by wires or other conductors, is the same, and may be measured by connecting by a conducting wire any part of the conducting body with any insulated electrometer of sufficient delicacy. For measuring the potential I use any suitable electrometer. Electrometers hitherto in use, such as the gold leaf or the pith ball electrometer, are not sufficiently sensitive to measure the potential, which can be conveniently communicated to a telegraph wire; I therefore use one of those next described. One of the electrometers which I use, and which from its indications depending on the potential of the indicator, as well as on the difference of potentials to be measured, may be called the heterostatic electrometer, consists of the following parts:—

1. A testing conductor, which consists of two, four, or any even number of separate pieces of metal, but which may be most easily described by first supposing them to form one piece, and then describing how that piece is to be divided. The testing conductor, then, consists of a piece of metal turned to the form of a true solid of revolution of such a shape that when the indicator hereafter described turns about the axis of figure of the solid the end of the indicator may be exposed to the action of as large a part as conveniently may be of the testing conductor. Thus the testing conductor may be as shewn in the Figure, a flat circular ring placed horizontally, or it may be a circular plate placed horizontally, the end of the indicator in either case moving just over the upper

surface of the testing conductor; or it may be a cylindrical ring, with its axis of figure vertical, the end of the indicator then moving just inside the ring; or it may be such a flat circular ring or plate surrounded with such a cylindrical ring, so as to be of the shape of a shallow compass bowl, the end of the indicator then moving as the end of the ordinary compass needle; or it may be of the shape last described, with the addition of a flat circular ring placed above the indicator, some additional contrivance which may be easily arranged being then made to allow the position of the indicator to be observed. This testing conductor is to be divided into two, four, six, or any even number of equal sectors, by slits at the intersections with it of planes passing through the axis of figure, and the sectors separated from each other by the smallest possible interval that will prevent actual contact; the thickness of a sheet of paper will be sufficient if the instrument be well made and carefully adjusted. It will be convenient first to describe the instrument and the mode of using it when the testing conductor is divided into two sectors, and then to describe the variations caused by dividing the testing conductor into four or more sectors.

2. An indicator.—By the term "indicator" I mean here and in the following parts of the Specification, a body acted on by the forces required to be measured, and suspended or supported in such a way as by its angular motion to measure or indicate the amount or change of those forces. The particular form and construction of the indicator in each case will be described.

In the instrument now describing the indicator consists of a thin conducting slip of metal, suspended at one end by a nonconducting filament, and kept horizontal by a counterpoise, and kept at a constant or sensibly constant potential by means of the conductor next described.

3. A conductor, connecting the indicator with a body of large electrical capacity, kept electrified to a constant potential, the difference of which from the potential of either of the bodies the difference of whose potential is to be measured is very large compared with the last-mentioned difference.

4. A conductor to connect one of the parts of the testing conductor with the telegraphic wire to be tested, and another conductor to connect the other part of the testing conductor with the earth, or with another part of the telegraphic wire or any other body, the difference of potential between which and the first part of the telegraphic wire is to be measured.

5. A case or cases to enclose the parts herein-before described with an atmosphere artificially dried to preserve the indicator from disturbances by currents of air or otherwise, and to maintain good insulation in the various parts in which insulation is required.

6. A graduated scale or other arrangement for allowing the position of the indicator to be observed at any time.

The principle of the action of the instrument is the following:—When both parts of the testing conductor are in connection with one another or otherwise electrified to the same potential, they do not disturb or affect the position of the indicator, and this by virtue of the shape of the testing conductor, being that of a solid of revolution, having its axis of figure coincident with the axis of motion of the indicator. If it were of any other shape there would be an inductive effect between it and the electrified indicator, which would give the indicator a tendency to point in particular directions. The indicator is now to be adjusted by the torsion head, so that its end rests immediately over or opposite one of the slits. This having been done, when the two parts of the testing conductor are electrified to different potentials, the indicator deviates to the side of that part, the potential of which differs most from the potential of the indicator. By keeping the indicator electrified in manner hereinbefore mentioned to a high potential, either positive or negative, the effects of induction between the indicator and the testing conductor are obviated, and the sensibility of the instrument is greatly increased, and we have the further advantage of being able to distinguish by the direction in which the indicator moves whether the potential of the conductor tested or the difference of potentials of the two is positive or negative, a result not given directly by an idiostatic electrometer such as that next described. When we wish to measure the difference of potential between two conductors we bring one part of the testing conductor into connection with one of the conductors, the other into connection with the other, and observe the angular deflection of the indicator, or we may turn the torsion head till the indicator is brought back to its original position, and observe the amount of torsion required. If one of the two conductors so tested is the earth, then as its potential is considered as zero, we get a measure simply of the potential of the other conductor.

In the instrument as described there is the disadvantage that the indicator is subject on being highly electrified to be tilted down or otherwise drawn into contact with the testing conductor and to be discharged. This is obviated by dividing the testing conductor into four equal sectors, and connecting two opposite quadrants with the conductor to be tested, the other two with the earth. The indicator then is suspended by its centre, and made to extend equally in both directions from the suspending filament, and the tendency to tilting or to be otherwise drawn into contact with the testing conductor is obviated, and the power of the instrument doubled.

The testing conductor may be divided into six equal sectors, and three alternate

sectors connected with the conductor to be tested, and the other three with the earth. In this case the indicator will be of the form of a three-rayed star, the rays in the position of equilibrium being immediately over or opposite alternate slits, and in like manner the testing conductor may be divided into eight or any even number of sectors, the indicator being in the form of a star with half as many rays as there are sectors, but it is not probable that any increase above four sectors will compensate for the increased expense and trouble in construction and adjustment.

Figure 1 shews, on a scale of about one quarter of the actual dimensions, one mode of constructing this electrometer in its simplest form, herein-before described. A, B, testing conductor, consisting of a flat circular ring divided into two sectors by very narrow slits at C, C, and having a scale marked on its upper surface. Each sector has an insulating support or supports with three levelling screws to adjust it to a truly horizontal plane and to a given elevation, permitting it also the requisite horizontal motion, and steadied by springs, for which clamps may be substituted. D, indicator, consisting of a flat thin slip of aluminium or other suitable material with a counterpoise M. E, fibre of glass or other suitable material, by which the indicator is suspended, with a torsion head and graduated circle of the usual construction; F, conductor connecting the indicator with the electrified body I, which conductor may consist of a wire dipping into a cup containing a conducting liquid; this mode of connection will be again mentioned under the head of the fifth part of my Invention. G, conductor for connecting one sector of the testing conductor with the conductor to be tested; H, conductor for connecting the other sector of the testing conductor with the earth or the other conductor to be tested; I, electrified body, which in the Figure is a Leyden jar charged to a high potential in the usual way from an electrical machine, the conducting wire being in connection with the internal coating of the jar, and the external coating in connection with the earth; K, glass cylinder or other case containing a dry atmosphere; L, conductor for charging and testing the body I; N, vessel containing sulphuric acid or other absorbent material for drying the air in the case.

For testing the insulation of the telegraphic wire in cases in which it is desired to give it a very high potential in testing it, and also for testing the amount and permanency of the potential in the electrified body I, part of the heterostatic electrometer herein-before described and generally for measuring electrostatic potential where a less delicate measure is required than that for which the first-described electrometer is adapted, I use an electrometer which from its indications depending simply on its own potential as communicated

by connection with the bodies to be tested, may be called an idiostatic electrometer, and which answers to the following description:—

An indicator, consisting of a slip of metal suspended by its centre, and connected with two pieces of metal fixed near its ends, and so arranged that the indicator can swing freely in one direction in a horizontal plane, and is stopped by the pieces of metal from swinging in the other. If this combination be insulated and brought into connection with the electrified conductor to be tested, whether its potential be positive or negative, the indicator is deflected. By enclosing it in a hollow metallic cylinder with metallic ends, herein-after referred to as the drum, in contact with the earth, but not with the indicator, the deflection of the indicator is increased, and the indicator is at the same time protected from the effects of irregular induction from surrounding bodies, and conversely if the drum be insulated and connected with the electrified conductor to be tested, and the combination of pieces of metal and indicator be connected with the earth, a like amount of deflection of the indicator is produced. Figure 2 shews, on a scale of about one-quarter of the actual dimensions, one mode of constructing this idiostatic electrometer. A, vessel containing sulphuric acid, or other absorbent material to dry the air in the air-tight case C, which stands on hollow pillars B, the interiors of which make a communication between A and C; D, a cylindrical metallic drum, with its axis of figure vertical, enclosed in the case C, and shewn by dotted lines; this drum is supported by glass or other insulating pillars, which traverse the hollow pillars, and it has in the centre of its upper and lower ends circular holes, large enough to permit the tube F to pass through without contact. E, insulated conductor, by which the drum D can be connected with the body to be tested; F, vertical metal tube, capable of being turned into various positions about its vertical axis; the position of this tube is indicated by an index attached to it, which points to a circular graduated scale on the top of the case C; the vertical tube F traverses the case C and drum D; its construction within the drum at the point marked H will be afterwards described; at I it has or may have a glazed opening, to permit the access of light to a mirror to be afterwards mentioned. G, torsion head, carrying a fibre or wire which traverses the axis of the tube F, as shewn by a vertical dotted line; from G down to H this fibre in the instruments I have constructed is of glass, but if a metallic wire sufficiently fine could be procured I should prefer it, and in that case the wire below H, and the cup of conducting liquid afterwards mentioned, might be dispensed with; at H the fibre or wire carries the indicator, to be afterwards mentioned; from the indicator a wire goes down and communicates with the tube F, and with the earth by dipping into a

small vessel of conducting liquid. The deflection of the indicator is indicated either by the reflection of light from a small mirror carried by this wire at I, or by the position of a very light index carried by it at K, moving within a glass case, and pointing to a graduated arc. Either or both of these methods may be employed. Figure 3 is a horizontal section of the interior of the drum D, near the level of the point H. L is a horizontal section of the vertical tube F, which here has two small openings in its opposite sides, to allow of the passage and motion of the indicator N, N; M, M, are two metallic arms projecting from the tube at opposite edges of its two openings. The indicator N, N, is of aluminium, or other suitable metal, and is carried by the fibre or wire before mentioned. When the electrical condition of the apparatus is undisturbed, the tube and the suspending fibre or wire are to be adjusted until the indicator N, N, hangs nearly in contact with the arms M, M. When the tube F and the indicator are connected with the earth, and the drum D with the conductor which is to be tested, the bar N, N, is repelled by the arms M, M, and the repulsive force measured by the deflection of the indicator, or by the torsion of the suspending fibre or wire required to bring back the indicator to its original position, measures the difference between the potential of the conductor tested and of the earth.

This difference of potential may also be measured by connecting the conductor to be tested with the tube and indicator, insulating them from the earth, and bringing the drum in connection with the earth, but this mode of using the instrument I have found to be less convenient than that first described; in this way too, the difference of the potentials of any two conductors may be measured.

Second Part.—I also test the insulation of a telegraphic wire by comparing its resistance to the flow of electricity from a constant source with the resistance of a standard wire to the flow of electricity from the same, or another constant source.

A standard wire is one perfectly insulated, and whose resistance to electromotive force is known, and which resistance may be conveniently expressed in terms of the resistance of a certain length of the telegraphic wire to be tested if perfectly insulated. Several standard wires of different resistances should be at hand to be used. One of the ways in which I make the observation, is by applying a battery to send a current through the standard wire into the telegraph wire, insulated as much as possible, and then to apply the electrodes of a tangent galvanometer, or other galvanometer, or of an electrometer, such as either of those described, or of any other kind, first, to the two ends of the standard wire, and next to the end of the standard wire which is connected

with the telegraph wire to be tested and to the earth. The resistance of the standard wire is to the resistance to be tested, as the difference of potentials at the two extremities of the standard wire is to the difference between the potentials at the end of the standard wire in connection with the telegraph wire and the earth.

Third Part.—I test a submarine telegraph wire during the operation of laying it by measuring from time to time the strength of currents produced in it by the electro-motive force of a constant battery or batteries, and that by means of various forms of galvanometer which I have invented for the special purpose of being used at sea. The chief peculiarity of the different kinds of marine galvanometer which I have invented consists in the moveable magnet, which is the indicator, being supported by means of one, two, three, or more threads, wires, or fibres in such a manner as to allow it the requisite degree of freedom to move, and to give it the requisite degree of stability independently of gravity and terrestrial magnetism, and in such a manner as to be as little as possible disturbed by these forces, and by the reaction of its own inertia against the inequalities of the ships' motion. When one thread, wire, or fibre is used the indicator is fixed to the middle of and at right angles to the thread, wire, or fibre which should pass as nearly as possible through the centre of gravity of the indicator. The thread, wire, or fibre is tightened by screws, and adjusted by torsion heads at both ends. When two or four threads, wires, or fibres are used, then the mode of support is that described in the fourth part of this Specification.

For the purpose of giving increased steadiness to the indicator, I sometimes use, in addition to the mode of suspension herein-before indicated, a fixed magnet placed in a suitable position in its neighbourhood. By the word "magnet" I mean any body which exerts magnetic force. The apparatus which I prefer for observing at any time the angular deflection of the indicator, is a mirror attached to that body and reflecting a ray of light either after or before, or after and before the ray passes through one or more lenses, so as to be sent to, and brought to a focus at different parts of a graduated screen, as the indicator assumes different positions. The method of observing the position of the indicator will again be referred to under the head of the thirteenth part of my Invention.

The frame of the galvanometer is fixed by screws to one end of a board, at the other end of which is a lamp having a camphine or other very brilliant flame for throwing a beam of light, and also a graduated screen on which the beam reflected from the mirror is thrown, so as to indicate the angular position of the indicator. The board is supported from below by means of springs

on a stand fixed to the ship. For this purpose I prefer spiral springs of the kind known as furniture springs. Round the stand and fixed to it is a rail, from which springs or elastic bands go to a rail fixed to the board, so as to moderate the horizontal oscillation of the board and galvanometer.

Fourth Part.—I use a double bifilar suspension for the indicator in any electrometer, galvanometer, relay, or generally in any instrument used for testing, or for working electric telegraphs by means of an indicator. This suspension I have invented to give any requisite degree of stability, or of instability to the indicator in any position of equilibrium.

Figures 7 and 8 shew how this part of my Invention is performed. In each of those Figures G H represents the indicator and A I, B K, C I, D K, four fibres or wires, by means of which the indicator is attached to four points, A, B, C, D. The dotted line L, M, is an imaginary line perpendicular to the two lines A, B, C, D, which join the points of suspension in pairs, and also perpendicular, or nearly so, to the plane in which the indicator moves. The dotted line E, F, represents the position in which the indicator tends to place itself when undisturbed; and the deviation of the indicator from that position, that is, the angle between G, H, and E, F, indicates the direction and amount of force derived from the arrangement by which the indicator is acted on, tending to make it return to or further diverge from its position of equilibrium, according as the equilibrium is stable or unstable. When A, B, is parallel to C, D, as in Figure 7, E, F, is also parallel to A, B, and C, D; the equilibrium is then stable and the stability greatest. As A, B, or C, D, or both, are moved so as not to be parallel, as in Figure 8, the direction of E, F, is intermediate between the directions of A, B, and C, D, and the stability is less than in the former case; and the more the direction of A, B, differs from that of C, D, the less is the stability, until the directions of A, B, and C, D, differ by more than one hundred and eighty degrees, when (if the indicator is supported by fibres having no sensible independent elasticity of torsion) the equilibrium is unstable; and stops, at equal distances on each side of the position of the equilibrium, are to be used to prevent the indicator from diverging by more than a convenient angle from the position of equilibrium. When the indicator is supported by wires having an independent elasticity of torsion, this elasticity increases the stability, or diminishes the instability, which the indicator would otherwise have from the mode of suspension; and a greater angular separation between A, B, and C, D, must be used to give the same degree of stability and instability as in the case of fibres without sensible elasticity of torsion.

The stability is adjusted to any required degree, so as to adapt the instru-

ment to the measurement of more or less intense force, by making one or both of the two pieces A, B, and C, D, to which the fibres are attached respectively, capable of rotation about the line L, M, so that the lines A, B, and C, D, can be adjusted to and fixed at such relative angular positions as shall be found by trial to give the degree of stability or instability required under the circumstances of the case.

When the indicator is directed by fixed magnets or otherwise, and it is desirable to have the means of diminishing its stability, then it may be suspended by a double bifilar suspension in the mode described, arranged in a manner which would, independently of the magnet, give instability. This will diminish the too great stability which it has from the magnet.

Fifth Part.—In using the method of suspension described in Part 4, or any of the ordinary modes of suspension by fibres or wire, when any one of the supporting or guiding wires or filaments in any of these arrangements is of a conducting substance, and of sufficient conductivity, and when it is desired to make or break an electric circuit or electric circuits by the motions of the indicator, I use that wire or filament, or one or more of those wires or filaments, for bringing into circuit a piece or pieces of platinum or other metal attached to the indicator, touching a metal stop or detached from the same, according as the indicator is on one side or the other of its mean position, or any other suitable arrangement for making and breaking circuit. When none of the suspending or directing filaments are of conducting material, and when it is desired to have a circuit or circuits made or broken by the motion of the indicator, I use a vessel containing a conducting liquid, and a conductor connected with the indicator dipping into the conducting liquid to maintain the electric communication between the indicator and the fixed parts of the circuit or circuits.

Sixth Part.—I use electro-motive forces, of several different positive and negative strengths, to give different signals in telegraphing; and for this purpose, and also when it is convenient to use a relay for transmitting such a system of different signals through any station by the aid of a local battery, or otherwise, I use a coil with several moveable magnets or indicators in its neighbourhood acted on by the coil when a current is transmitted, and also so acted upon by the tension, or torsion, or both of filaments, or the deflecting action of fixed magnets other than the earth, and by stops, that one set of the indicators will not move when the current is in one direction, but will move if a sufficient strength of current in the opposite direction be applied, and vice versâ, as to the other set of indicators. The position of the indicators and the elastic or other force which opposes their motion are so arranged, that, for the

lowest strength of current in one direction, one indicator of one set only will move; for the second strength, two of the same set will move; for the third strength, three, and so on; and so, vice versa, for the other set of indicators, when the current is in the contrary direction. When these indicators are used simply as receiving instruments, and read off directly by an observer, the number of indicators which move distinguishes the different signals; if used with a relay as a transmitting or recording instrument, then, when any one of these moveable magnets moves, it breaks or makes, or breaks and makes electric communication in a local circuit or circuits, so as to cause the corresponding degree of electro-motive force to be applied to the part of the telegraph line along which the electric signals are to be forwarded, or to the recording apparatus.

Seventh Part.—I have also invented another kind of galvanometric relay or receiving instrument, consisting, besides the ordinary parts, of,—

First, a single primary magnet or indicator moveable in a horizontal plane, and when in a position of equilibrium pointing to the magnetic north, and which, by ordinary modes, may be made to move to the east when the current is one direction, and to the west when the current is in the other direction; or two primary magnets or indicators, one of which is prevented by stops from moving to the east, and the other is prevented by stops from moving to the west.

Second, two or more small secondary magnets or indicators moveable in the same horizontal plane about fixed axes; these axes are placed at successive distances along and outside the arc north or south, but (to fix ideas) I will say north of the primary indicator. One secondary indicator may be due north of the primary indicator, and without stops; one half of the rest of the secondary indicators are placed at successive distances to the east, each with a stop which prevents its north end from moving to the east, and the other half at like successive distances to the west, and each with a stop which prevents its north end from moving to the west. When the primary indicator is in its undisturbed position' all the secondary indicators are held against the stops, except the first or central one, which is then also pointing north. When a positive current of the first strength is sent through the wire, the primary indicator, or one of the two primary indicators, moves through a given angle to the east or west; but say, (to fix ideas,) to the east, and moves only the first of the easterly set of the secondary indicators, the north end of such secondary indicator moving to the west. When a positive current of the second strength is sent through the wire, the primary indicator is deflected through a greater angle to the east, and the second of the same set of the secondary indicators is moved.

When a positive current of the third strength is sent through the wire, the primary indicator is deflected through a still greater angle to the east, and the third of the same set of the secondary indicators is moved, and so on; and so vice versâ, as regards the west set of secondary indicators when negative currents of the first, second, and third strength are sent through the wire. The motions of the secondary indicators may be observed and read off or recorded in any of the ways now in use, or in any of those described in this Specification adapted to the purpose, or may be used to make or break contact for local batteries, and thus be used as a relay for a transmitting or recording instrument, or in any operations connected with the manufacture or use of electric telegraphs for which it is suited.

Although in what precedes I have, for distinctness, supposed the primary and secondary indicators in their undisturbed position to point north and south, they may often be more conveniently directed in some other direction by fixed magnets, or by any of the modes of suspension described herein; in that case, for north, south, east, and west, in the preceding description, must be substituted corresponding directions relative to the actual position of undisturbed equilibrium.

Eighth Part.—I use either of the electrometers described in the first part as a receiving instrument, or an instrument to be used in making comparisons of clocks, or in giving time, or for any other purpose connected with the manufacture or use of electric telegraphs worked otherwise than by frictional electricity. I prefer for this purpose the electrometer first described above.

Ninth Part.—I also use thermal effects produced by radiant heat reflected from a mirror or reflecting surface of any kind, attached to the indicator of a receiving instrument, for the purpose of having the indications recorded. The thermal effects which I thus use may be either, first, the melting of wax or of any other fusible substance, forming a layer which is moved with a steady motion across the line of motion of the beam of radiant heat, or any chemical or other change produced in the quality or appearance of any substance by heat; or, secondly, thermo-electric effects in local circuits excited by the radiant heat. The last-mentioned kind of effects may be used in the construction of a third kind of galvanometric relay, in which one or two or more thermo-electric circuits are excited according to the distance, and the direction of any excursion of the beam of reflected radiant heat, and produce motions in moveable magnets or indicators, by which the electric currents to do the work wanted may be checked or permitted to pass as required.

Tenth Part.—I use photography for recording electric signals as indicated, by motions of an indicator or indicators, either by light reflected from a mirror

attached to the indicator, or transmitted by an aperture or transparent part in the indicator, or by influences of a shadow or image of the indicator, or of the shadow or image of any part of it. In performing this process, I use a band or piece of photographic paper or other substance sensitive to photographic action; which by any ordinary mechanism I cause to travel at a steady rate across the line of motion of the indicating beam whose movements are recorded by the marks made on the paper or other sensitive substance.

Eleventh Part.—I use a relay, by which messages are transmitted simultaneously from two or more submarine cables into a smaller number of land wires, or a smaller number of submarine wires of shorter length, or the converse, or generally in any case when it is desired to transmit messages from one wire or a number of wires into and along a different number of wires. The system by which I perform this is sufficiently explained by the plan I follow in using two submarine lines in connection with one shorter submarine line or one land line, which is as follows:—Each singly read or recorded indication from each of the long submarine lines, makes, by any kind of relay that is convenient, a corresponding secondary electric signal, single or compound, and these secondary electric signals are made at equal intervals of time from one another, and in general alternately, as they come from the two submarine lines. When it can be arranged that the submarine lines are to be worked at the remote end so as to send signals at alternate intervals of time, the kind of relay which is required is merely one in which signals from two different submarine lines are forwarded indifferently at the instant as they come. A useful application of this part of my Invention consists in giving the means of sending two or more messages at the same time along the same telegraph wire from different instruments at the same station. Each instrument has a conductor leading to the telegraph wire. The keys or handles by which each instrument is worked are kept locked, so as to be incapable of motion, except during certain definite periods, during which the keys or handles of all the other instruments are locked, so that the keys of one instrument only can move at any one time, and the keys of all the instruments used can be successively moved. This may be accomplished by various mechanical arrangements; for example, each key may have a pin projecting from its under side; and below the row of pins there may be a cylinder rotating by clockwork at an uniform rate, with a longitudinal groove of a certain width along it, so that the keys of the instrument in question can only be depressed during the period when the groove is below the row of pins. Then, either by placing all the sets of keys above one cylinder, having a groove for each instrument so arranged that the keys of no two instruments are ever above the corresponding groove at the

same time or by having a separate cylinder under the set of keys of each instrument, but the cylinders rotating at one and the same speed and so arranged that the keys of no two instruments are ever opposite the corresponding groove at the same time, the rows of keys of the several instruments may be liberated in succession at successive times, so that two or more clerks may work at two or more instruments at the same time, each sending a separate message, and the two or more messages will be transmitted together by successive alternate signals, which can be arranged so as to separate the messages at the distant station according to a preconcerted system; for example, suppose that at one station there are two instruments and two clerks, and that at the other station the following series of signals arrive, P,F,R,R,O,E,T,E,E,T,C,R,T,A,I,D,O,E,N, a clerk at the second station taking these letters alternately, finds that the first clerk transmitted the word PROTECTION, and the second the words FREE TRADE. In any case in which signals can be transmitted by the conductor at a more rapid rate than one clerk can work his transmitting instrument, this method will save much time. The particular mechanism employed for unlocking the several sets of keys in succession may be varied by any one who is familiar with machine or instrument making. I have already described one kind of mechanism for that purpose; another kind in which cams and levers are employed, will be herein-after described under the head of the fourteenth part of my Invention.

Twelfth Part.—I use electric sparks excited by a Ruhmkorff coil or any other convenient instrument, and passing between any part of the indicator and a sheet of matter fixed or carried along by a regular motion near it to record, by impressions, by chemical changes, or by perforations produced by these sparks, the motions of the indicator. I also use electric currents sent through a conducting liquid, covering part of the moveable body so as to make impressions, chemical or other, on a sheet also covered by a liquid. In using electric sparks to record the indications of a moveable body in a galvanometer or galvanometric relay employed for telegraph purposes, I employ a regular succession of sparks, following one another at very short intervals of time, each making a mark on the paper or other sheet receiving the impression or perforation. In using this part of my Invention, I prefer to cause a strip of paper sensitive to photographic action, or otherwise, to travel with a steady motion across the path of the end of the indicator over a metal plate, above which plate the end of a conductor projecting from, or forming part of the indicator; moves to and fro in consequence of the action of the current transmitting signals. The series of sparks excited by the Ruhmkorff coil or other instrument takes place between the before-mentioned end of a conductor and the

metal plate, and makes a series of marks on the paper either by photographic action or perforation, or both. The result is an undulating curve of dots, the character and succession of the undulations of which give the different signals desired to be sent.

Thirteenth Part.—I use an apparatus by means of which electric signals may be read off by observing the amount, greater or less, of motion of an indicator, and that, by observing the same directly, or by observing the motion of a spot of light reflected from a mirror carried by the indicator, and thrown on a graduated screen, or received by a telescope, such greater or less amount of motion being produced by currents of greater or less strength, regulated as herein-after described. For this purpose I prefer to attach to the indicator a very light mirror reflecting a beam of light, which beam produces a luminous spot or line on a graduated screen, by the motions of which spot or line the corresponding motions of the indicator are made visible. It is useful to employ a lens for concentrating and bringing to a focus the beam of light, in which case the screen should be at or near the focus of the lens. When I use a lens for the before-mentioned purpose, I prefer that it should form part of the casing by which the indicator is protected from currents of air; the illuminating beam of light enters the casing through the lens, is reflected from the mirror, and leaves the casing through the lens again. Figure 4 represents, on a scale somewhat larger than the actual scale, the indicator which I prefer for a galvanometer with one thread, wire, or fibre; A is a cylinder of glass with glass ends; I usually make one or both ends of the form of lenses; B, a small mirror hung by the fibre D, in the interior of the cylinder; C, C, a small steel magnet or indicator fixed to the mirror; a small circular plate placed behind the indicator and moved backwards and forwards by a screw, forms an adjustable stop for checking its oscillations and limiting the range. Figure 5 represents, on a scale about one-quarter of the actual dimensions, one of the galvanometers which I use. A is the bobbin with its coil of conducting wire fixed upon a stand, which has levelling screws; B, B, B, B, B, B, B, studs connected wfth the coil at different points, so as to enable the operator to send the electric current to be measured through different lengths of coil, according to the sensibility required in the instrument; C, central aperture in the bobbin, into which is inserted the cylinder containing the indicator represented in Figure 4; D, E, handles for adjusting the position of a fixed magnet, which is concealed beneath the stand of the galvanometer, and which regulates the stability of the indicator. One of these handles turns a tangent screw which drives a horizontal pinion so as to turn

the magnet into any required direction; the other handle turns a vertical pinion which works into a vertical rack, so as to place the magnet at any required depth below the bobbin. Figure 6 represents another of the galvanometers which I use. A, bobbin with the coil for the current to be measured; C, opening, containing the magnet or indicator with its mirror as before; B, B, a pair of bobbins with the coil, through which a constant current is transmitted. The axis of this coil is perpendicular to that of the coil A; when no current traverses the coil A the indicator places itself along the axis of B, B; when a current traverses the coil A the indicator deviates through an angle depending on the strength of that current; D, pinion, and E, clamp screw for adjusting the angular positions of the coils B, B, and A; the adjusting coil B, B, will be again referred to under the head of the twentieth part of my Invention.

Fourteenth Part.—In long lines of submarine telegraph, I use apparatus by which, for a single signal, an electric current of a stated strength is as rapidly instituted in a telegraph wire as possible, and maintained as nearly as possible at the stated strength until an indication is taken from it by any of the receiving instruments, galvanometers, relays, or electrometers described above, or by any other which may be convenient. The indication must be of such a kind that from it, with due allowance for the electric condition of the wire as affected by previous operations, it may be possible to estimate what was the strength of current arranged for at the transmitting end. According to the strength of current (positive or negative) thus estimated, one number or another, one letter or another, one word or another, one piece of intelligence or another, is read off according to a pre-arranged code. I use a Daniell's or other constant battery, or any other electromotor by which definite and sufficiently exact measured amounts of electro-motive force can be applied for making electric signals of this kind. I use the following plan for making the current as rapidly as possible approach the stated strength for any signal, and that whatsoever may have been the strength employed in the signal immediately preceding it or in any of the preceding signals:—When the wire is unelectrified to begin with, then I apply first a stronger electro-motive force than that required to maintain the current at the stated strength for a short time, and after that I apply the electro-motive force just required to maintain a current at the stated strength, and continue such application until the time comes to make the next signal; I next apply, for a short time, an electro-motive force, differing from the last by a greater amount than that by which the electro-motive force corresponding to the new signal differs from it, after which

the electro-motive force simply required to maintain the stated strength corresponding to the new signal is applied, and held on until it is time to commence a third signal, and so on.

I also, in some cases, use the following plan:—I apply constant battery power during a certain measured interval of time, then another battery power during another equal interval of time, and so on, these degrees of power, equal or unequal, as the case may be, being each determined by calculation or otherwise, so as to compensate so far as is required the residual effects of preceding operations, and at the same time to produce a new effect constituting or contributing towards a new signal.

The method of performing this and similar operations will be best understood by an example such as the following:—To get a letter every three seconds, I apply, by means of a pendulum and clockwork apparatus during one second, a certain strength, say forty-eight, of positive electro-motive force, during the next second fifty of negative electro-motive force, during the third second twelve of positive electro-motive force. The effect at the receiving end of a certain length of line is to make the indicator move to a positive maximum of deflection corresponding to the letter required, and fall back to zero or nearly to zero before it commences to indicate the effect of a similar succession of operations made for another letter during the next three seconds. The proportionate strengths for different simple signals are the same for the same line of telegraph and speed of working, the absolute strengths alone being different. For different lines of telegraph, and different speeds of working, the proper proportions of the electro-motive forces in each case can best be found by experiment on the line itself.

In order to illustrate this part of my Invention, Figure 9 represents apparatus which I use in carrying it into effect, on a scale of about one-half of the actual dimensions. In order to render that Figure as easily intelligible as possible, I have simplified it in cases in which several parts or sets of parts of the apparatus are exactly similar to each other in construction and use, by shewing only one such part or set of parts; I have also omitted such ordinary and well-known details of mechanism and framework as any instrument maker can easily supply, and can vary at his discretion, because such details would complicate the Drawing, and conceal the essential features of the Invention which it illustrates. I wish it also to be understood that every conductor represented in the Drawing is insulated by the ordinary means of insulation from all electrical communication with other bodies, except such communications as are specially mentioned in the description.

A_1 and A_4, A_2 and A_5, A_3 and A_6, are three pairs of wires, connected with a

galvanic battery (not shewn) at such three pairs of points as are suitable for producing the three successive currents required for making a certain given signal, A_3, A_2, A_1, being the three conductors which, in order to produce that signal, are successively to be connected with the line wire, and A_6, A_5, A_4, those which are successively to be connected with the earth; these six wires are respectively connected with six studs B_1, B_2, B_3, B_4, B_5, B_6, fixed on a board underneath a key D; C_1, C_2, C_3, C_4, C_5, C_6, are six springs, which are brought into contact with the respective studs when the key is depressed, and which rise and break contact when the key is not held down; the key turns on a rod at E; there are as many keys, each with its six wires, six studs, and six springs, as there are distinct simple signals in the code of signals, but, according to the principle already stated, only one key with its adjuncts is shewn. F is an arbor made to rotate by clockwork; the motion of the clockwork is regulated by a pendulum and a dead-beat escapement; I have hitherto used a pendulum beating seconds; the arbor F makes one revolution consisting of twenty-four beats or jumps for each twenty-four swings of the pendulum. G is a circular cam having four equidistant teeth. H is a lever which is lifted and dropped once in every six beats by the teeth of the cam. J, a fixed stud to which is attached a spring for holding H down when not lifted by a tooth; for this spring a weight might be substituted. I, an arbor carrying the lever H, and also another lever K, which passes at L through an opening or slot in the key D; in that slot is seen a cross bar fixed to the key, and under the cross bar is a pin projecting from the lever K, and each key in the row of keys is provided with a similar lever, pin, and cross bar; when the lever H is not lifted, the pins projecting from the lever K, being below the cross bars of the keys, lock the keys and prevent their being depressed; when the lever H is lifted, the pins are all drawn back, and all the keys of the row are unlocked at once for an instant, and then locked again. Should the clerk using the instrument press upon any key it descends at the instant of unlocking, and when the keys are again locked the pin is above instead of below the cross bar of the depressed key, so that that key is held down, and the contact of its springs and studs maintained until the next unlocking; that is, for six beats of the clockwork. M_1, M_2, M_3, M_4, M_5, M_6, are six wires respectively connecting the six key springs C_1, C_2, C_3, C_4, C_5, C_6, with six springs N_1, N_2, N_3, N_4, N_5, N_6, which I call first cam springs. There is only one set of six first cam springs for the whole of the keys in a row; all the key springs corresponding to the springs C_1 for the several keys being connected with the single cam spring N_1, all the key springs corresponding to C_2 with the single cam spring N_2, and so on.

The three cam springs N_3, N_2, N_1, are made to communicate successively with the line wire at the same instants that the other three cam springs N_6, N_5, N_4, are made to communicate successively with the earth by means presently to be described. P_1, P_2, P_3, P_4, are four cams carried by the arbor F, which I call respectively P_1, P_3, the line cams, and P_2, P_4, the earth cams. Each of those cams is insulated from the arbor, and each consists of two discs of different diameters. The smaller discs are circular, and are always in contact respectively with the springs Q_1, Q_2, Q_3, Q_4, which I call the second cam springs. Each of the larger discs has four similar equidistant projections, whose outer surfaces are portions of one cylinder, and each of those projections occupies a little less than one-twelfth part of the circumference of the disc. The positions of the cams on the arbor and those of the ends of the six first cam springs, are so adjusted that, when the arbor, rotates, the projections of the two pairs of cams come into contact successively with the ends of the three pairs of first cam springs in the following order; that is to say, immediately on the unlocking of the keys the pair of first cam springs N_3, N_6, are brought into communication with the cams P_1, P_2, and through them with the pair of second cam springs Q_1, Q_2; next, the pair of first cam springs N_2, N_5, are brought into communication with the pair of cams P_3, P_4, and through them with the pair of second cam springs Q_3, Q_4; and, lastly, the pair of first cam springs N_1, N_4, are brought into communication with the pair of cams P_1, P_2, and through them with the pair of second cam springs Q_1, Q_2, and so on in rotation. The second cam springs Q_1 Q_2, Q_3, Q_4, communicate respectively by wires R_1, R_2, R_3, R_4, with two pairs of studs S_1, S_2, S_3, S_4. U is part of the rod of the pendulum, which regulates the motion of the clockwork. T_1, T_2, are a pair of flat springs, which I call the pendulum springs, insulated from each other, and fixed across the pendulum rod, by which they are carried. T_1 communicates through an extensible conductor V with the line wire, and T_2 communicates through an extensible conductor V_2 with the earth. When the pendulum is to the right of the vertical position the springs T_1, T_2, are in contact with the studs S_1, S_2; when the pendulum is to the left of the vertical position the springs T_1, T_2, are in contact with the studs S_3, S_4; when the pendulum is in the act of passing the vertical the springs T_1, T_2, are not in contact with any of those studs. The effect of this is, that, during the second half of each swing of the pendulum towards the right, and during the first half of each swing towards the left, the line cam P_1 communicates through Q_1, R_1, S_1, T_1, and V_1 with the line wire, and the earth cam P_2 communicates through Q_2, R_2, S_2, T_2, and V_2

with the earth; and that during the second half of each swing towards the left, and the first half of each swing towards the right, the line cam P_3 communicates through Q_3, R_3, S_3, T_1, and V_1 with the line wire; and the earth cam P_4 communicates through Q_4, R_4, S_4, T_2, and V_2 with the earth. The combined effect of the whole apparatus is this:—When the clerk presses on a given key the locking and unlocking apparatus allows the key to descend at a certain instant, and holds it down for six beats of the clockwork, in the course of which time the six key springs and their studs maintain two portions of each of the three circuits required for the three currents proper to produce the signal wanted. By the action of the three pairs of first cam springs, and of the two line cams and two earth cams, two other portions of each of those three circuits are maintained for the three circuits successively. By the action of the pendulum and its springs each circuit is completed in succession, and maintained complete during a definite interval of time, being that of two half swings of the pendulum; that is to say, one second. I prefer to have a second row of keys on the same instrument; in that case, either by suitably placing the locking and unlocking lever of the second row corresponding to H, or by having a second cam corresponding to G, I cause the second row of keys to be unlocked at the instants exactly midway between the instants at which the first row of keys is unlocked. I have also a second set of first cam springs, corresponding to those marked N_1, &c., for the second row of keys, which springs in the Figure are marked N, and numbered from 7 to 12, and the wires which connect them with the key springs of the second row are marked M, and numbered from 7 to 12 also, but the second row of keys is not shewn. The contacts for making the circuits through the pairs of springs numbered 9 and 12, 8 and 11, 7 and 10, take place in succession during the interval following that which is occupied by the contacts for making the circuits belonging to the first row of keys. The two rows of keys may be used either to give a more rapid succession and a greater variety of signals than one row can conveniently produce, or to enable two clerks to work at the same time according to the method already described under the head of the eleventh part of my Invention. Although I have now described an instrument regulated by clockwork for carrying into effect the fourteenth part of my Invention, I wish it to be understood that that part of my Invention is also capable of being carried into effect, and that I sometimes do carry it into effect by instruments in which the duration of each current is regulated by hand, the clerk or operator having a metronome, a clock beating rapidly, or other suitable instrument near him to regulate his estimation of time; and for

that purpose I have a set of keys, each of which while depressed causes a certain fixed amount of electro-motive force to be applied to the telegraph wire; and to make a given signal, a certain specified pair or set of keys are depressed in a specified order, during specified intervals of time determined by experiment and calculation, as herein-before stated. One convenient arrangement is as follows:—There are two rows of keys, an upper and a lower, each containing the same number of keys. Each key of the upper row being depressed maintains a certain amount of electro-motive force in the telegraph wire, and the key immediately below in the lower row maintains the same force in the opposite direction. When none of the keys are depressed the telegraph wire is connected with the earth. To make a current in a given direction at the remote end of a long line of telegraph wire, which shall rise rapidly to a stated strength, and then fall rapidly to zero, or nearly so, an electro-motive force of a given amount is to be applied at the near end, first in the direction of the desired current for a certain time, and then an equal electro-motive force is to be applied in the opposite direction for a certain time of less duration than the first, the proper intervals of time being sensibly the same for all required strengths of current to be produced at the remote end are found, once for all, by experiment. A more accurate mode of securing that the different electro-motive forces are applied for the proper intervals of time, which I also use, is to make and break the contacts by means of a pendulum, so constructed as to swing on one side of its point of rest in a different time from that in which it swings on the other side, these two times being arranged so as to be the times for applying the two different forces. I also attain the same object by using a wheel moved by clockwork or other motive power giving a regulated motion, or moved by hand and regulated by a fly wheel or governor, and having cams adjusted so as to make and break contact at the proper intervals.

Fifteenth Part.—When it is desired to work through a submarine line, or through a very long air line, in both directions at once, then, in order to avoid the comparatively violent action which is caused in the receiving instrument at the transmitting end, by transmitting signals from that end through it, I throw the receiving instrument at the transmitting end out of circuit during certain parts of the time during which a signal is being transmitted from that end. I regulate the time during which the signal is transmitted by such arrangements of wheels and cams as before described, and by a separate wheel on the same arbor with proper cams I regulate the times during which the receiving instrument is thrown out of circuit.

Sixteenth Part.—I compensate the effects produced by currents transmitted from one end on the indicator of the receiving instrument at that end, so that the indications of that instrument are either not sensibly affected by them, or that the indications it would have given had it not been affected by them may be estimated. I produce that compensation by sending, while the receiving instrument at the transmitting end is in circuit, a current through a compensating coil near it, that compensating current acting upon the indicator of the receiving instrument at the transmitting end, at the same time that it is acted upon by the principal current of transmission, but in an opposite direction. The compensating current is not necessarily of the same strength with the current of transmission, but may be stronger or weaker in any proportion, according to the length, form, and position of the compensating coil, its strength being regulated so as to compensate the effect of the current of transmission. Thus I dispense with the resistance coil used to equalize the strength of the two currents in previous apparatus for the same purpose; the proper strength, and the proper law of variation of the strength of the compensating current are found by experiment, and the compensating current is produced, and its strength regulated, by a mechanical motion put into action by the depression of the same key which produced the principal current. I also compensate the effect of the current of transmission on the indicator of the receiving instrument by a magnet properly adjusted as to position, strength, and motion; these adjustments to be determined by trial. The kind of magnet most suitable for the purpose is an electro-magnet, consisting of a coil of wire, the strength of current through which will correspond to the electro-motive force causing the current of transmission; and one mode of mounting this electro-magnet is by attaching it to a wheel rotating once in the period of a single complete signal, the position of the magnet on which wheel is to be found by trial, so as to make the compensation most perfect.

Seventeenth Part.—In working in both directions at once, I make each electric signal as nearly as possible simultaneously at the two ends, or alternately at definite intervals of time; and for that purpose, I use a mechanical apparatus at each end, regulated according to an independent clock, or worked by clockwork, and I have electric comparisons of time between the two ends made as frequently as is necessary to make the mechanisms at the two ends keep time with one another as accurately as is required.

Eighteenth Part.—I use, when convenient or when desired for any object, two or more different galvanometers or other receiving instruments, either

each self-recording, or each read off by one or more observers, or all read off by one observer, but thrown into circuit in connection with the telegraph wire during intervals regulated by the same mechanism for keeping time as that which is used in making the signals, and which I have already described under the head of the fourteenth part of my Invention.

I do not proceed with that which is called in my Provisional Specification the nineteenth part of my Invention, and which is therein described in the following words, that is to say,—"For checking the motion of any moveable "indicator in a receiving instrument after its indication has been read off, I "propose to use a magnet moved by mechanism, or a vessel of liquid brought "up so as to cover part of the moveable body, and removed again if necessary "when a new indication is to be taken, or by turning or otherwise moving the "filaments or wires by which the body is supported, when it is so supported, "or by other suitable methods."

Twentieth Part.—For increasing, diminishing, or regulating to any desired degree the stability of the indicator of a galvanometer, or galvanometric relay, or of any instrument used in telegraphing, having a moveable indicator, I use wires conveying currents of electricity. The form of such wires may be varied, but I prefer coils in planes perpendicular to the position of equilibrium of the magnetic axis of the indicator, and I adjust the strength of the current in such coils, so as to produce the degree of stability which may be convenient. Such adjusting coils as are now described have already been mentioned under the head of the third part of my Invention, and are illustrated in Figure 6.

In my Provisional Specification the nature of the twenty-first part of my Invention is stated as follows:—"In the use of galvanometers, or galvanometric "relays, or of any other kind of relay or receiving instrument, I propose, in "order to compensate the effect of electrification of the telegraph wire "remaining over from previous signals, to use in the neighbourhood of the "moveable indicating body an electro-magnet or coil of wire conveying a "current instituted and regulated to produce the desired effect, or a steel or "other magnet, moved so as to produce the desired effect. When it is not "convenient to make allowance for such residual effects from previous signals "by calculation or otherwise, and when they are of such an amount as to "exercise a sensible disturbance if not compensated, I propose to use similar "apparatus, under similar conditions, in sending messages through either a "land or a submarine line, in both directions at once for the purpose of com- "pensating the effect on any receiving instrument due to signals transmitted "in the direction contrary to that from which the signals to receive which it

" is employed are coming;" but so far as I use and intend to proceed with that part of my Invention it is comprehended under the sixteenth part of my Invention, and the manner in which it is to be performed is herein-before described.

Twenty-second Part.—I use two mirrors attached to the indicators of two galvanometers, at the receiving end of, and receiving currents from one transmitting station by two separate telegraph lines; and I cause a ray of light to be reflected from these two mirrors in succession, and to be thrown on a screen, so as to give a visible effect, or by photographic or thermal influence, a recorded effect, by which any lines, figures, letters or symbols, drawn or written at the transmitting station upon an instrument adapted to give different degrees of electro-motive force to the two lines, according to the two independent variables thus dealt with may be written, drawn, or made visible at the receiving station. For transmitting a line, drawing, or writing of any kind by telegraph, I add a third telegraph wire, which is so connected and arranged, that when the tracing point at the transmitting station is lifted from the surface on which the curve is drawn, the indicating or marking beam of light is cut off at the receiving station. The manner of performing this part of my Invention may be varied in its details, but one method is as follows:—I prefer that the tracing point at the transmitting station should move on a horizontal plane. To fix the ideas, I distinguish the two components of the motion of the tracing point, as the north and south component, and the east and west component. A row of studs, running north and south, are connected with different points in a battery, so as to give a series of electro-motive forces of graduated strengths. A conductor, by means of a parallel motion, accompanies the tracing point in its north and south motion, and by touching one or other of the row of studs, establishes a current in one of the line wires, of a strength suitable to cause one of the mirrors at the receiving station to take an angular position, corresponding to the deviation of the tracing point to the north or south of its middle position. Another row of studs, running east and west, is connected with different points in another battery, so as to give a series of currents of graduated strengths. A conductor, by means of a parallel motion, accompanies the tracing point in its east and west motion, and, by touching one or other of the second row of studs, establishes a current in the second line wire of a strength suitable to cause the second mirror at the receiving station to take an angular position corresponding to the deviation of the tracing point to the east or west of its middle position. A ray, reflected successively from the two mirrors, performs motions sensibly similar to those of the tracing point. There is a screen which intercepts the beam,

unless drawn back by an electro-magnet. That magnet is made to act by a current traversing the third line wire, and part of the circuit conveying that current is formed by the tracing point and by a metal plate on which it is moved, so that by lifting the tracing point the beam is intercepted.

In using every part of my Invention the details may be varied without departing from the principle of the Invention.

I do not claim the mechanical movements and other elementary parts of the apparatus herein-before described otherwise than as herein-after mentioned; but what I do claim is, that which is stated or referred to in the following statement, that is to say:—

In connection with the first part of my Invention, I claim the method of testing a telegraphic conductor by the aid of electrostatic instruments in the manner herein-before described. I also claim the electrometer first herein-before described, so far as regards the use of a testing conductor, consisting of two or more parts, so formed and arranged that when all are electrified to the same potential, they shall have no directive effect on the indicator; and so far as regards the use, in combination with such a testing conductor, of an indicator independently charged to and maintained at a high potential; and I claim such instrument for all purposes connected with the testing, either in the course of manufacture or afterwards, or in the working of electric telegraphs, in which term I include all telegraphs worked by electricity, in whatever way such electricity is excited; and also so far as any of the other arrangements of the first mentioned electrometer are comprised in any other part of my claim.

I also claim the electrometer secondly herein-before described, so far as regards the use of the drum herein-before described enclosing the indicator, and also so far as regards the connecting the indicator with the earth, and insulating the drum, and connecting it with the conductor to be tested.

In connection with the second part of my Invention, I claim the method of testing the insulation of a telegraph wire therein described.

In conection with the third part of my Invention, I claim the marine galvanometers herein-before described, so far as regards the suspension of the indicator by a stretched fibre passing through its centre of gravity, and so far as any other parts of the arrangement are comprised in any other part of my claim.

In connection with the fourth part of my Invention, I claim the double bifilar suspension for indicators herein-before described.

In connection with the fourth and fifth parts of my Invention, I claim the

use of a suspending or supporting filament or filaments of the indicator of any of the instruments herein-before mentioned, as part of a conducting circuit connecting the indicator with another conductor. I also claim the use, for the same purpose, of a conductor dipping into a conducting liquid, in connection with the first and fifth parts of my Invention, and as described in the part of this Specification wherein those parts of my Invention are described. I do not claim the use of conducting filaments, or of conducting liquids, except in telegraphic apparatus.

In connection with the sixth part of my Invention, I claim the use for the indicator of a receiving instrument of two magnets, acted on either by the same coil or by different coils in circuit with the line, one of which magnets is deflected by a positive current, and is prevented by stops from being deflected by a negative current, and the other of which is deflected by a negative current, and is prevented by stops from being deflected by a positive current, and which indicators are kept in their mean position by any of the modes described in this Specification, or by any equivalent modes. And I also claim the use of two or more pairs of such indicators, whether kept in their mean positions by any of the modes herein-before described, or by any other mode, so arranged that the number of indicators set in motion by one current, depends on and is regulated by a regulated degree of strength of the transmitted current.

In connection with the seventh part of my Invention, I claim the use of secondary indicators to indicate, receive, record, or transmit signals, depending on the motions of primary magnets or indicators, in the manner herein-before described.

In connection with the eighth part of my Invention, I claim the use of electrometers as receiving instruments for telegraphic signals made by electricity other than frictional.

In connection with the ninth part of my Invention, I claim the use of the thermal effects of rays reflected from the indicator, in manner herein-before described, for the purpose of receiving, recording, or transmitting telegraphic signals.

In connection with the tenth part of my Invention, I claim the use of photography, in manner herein-before described, for receiving and recording telegraphic signals.

In connection with the eleventh part of my Invention, I claim the method herein-before described of transmitting messages between one or more conductors and a different number of conducters, and also the method herein-

before described, by which two or more messages can be sent at the same time from the same station along one telegraph wire.

In connection with the twelfth part of my Invention, I claim the use of electric sparks, in manner herein-before described, for receiving or recording telegraphic signals by means of marks, impressions, chemical changes, or perforations produced by these sparks.

In connection with the thirteenth part of my Invention, I claim the use of a transmitting instrument, adapted to send currents of various measured strengths, combined with a receiving instrument, adapted for receiving and recording the deflections of the indicator caused by the different strengths of current, and for giving a variety of signals thereby.

In connection with the fourteenth part of my Invention, I claim the methods and apparatus herein-before described for rapidly producing and for maintaining electric currents of stated strengths in telegraphic wires, and for discharging currents from such wires.

In connection with the fifteenth part of my Invention, I claim the arrangements for throwing the receiving instrument at the transmitting end out of circuit during part of the time during which a signal is being transmitted from that end, in the manner and for the purposes herein-before described.

In connection with the sixteenth part of my Invention, I claim the compensating the effects produced on the receiving instrument at the transmitting end by operations performed at that station by means of such a compensating current or moveable magnet as herein-before described.

In connection with the seventeenth part of my Invention, I claim the method herein-before described of transmitting signals in opposite directions at the same time along the same telegraph wire by working at regulated instants of time.

In connection with the eighteenth part of my Invention, I claim the use, for receiving and recording signals, of two or more instruments at or near the same station, thrown into operation during regulated intervals of time.

In connection with the so-called nineteenth part of my Invention, I claim nothing.

In connection with the twentieth part of my Invention, I claim the method and apparatus herein-before described for increasing, diminishing, or regulating the stability of a moveable magnet.

In connection with the twenty-first part of my Invention, I claim nothing beyond what has already been claimed in connection with the sixteenth part of my Invention.

In connection with the twenty-second part of my Invention, I claim the method and apparatus herein-before described for producing, at a receiving station, lines, figures, letters, or symbols of given shapes.

In witness whereof, I, the said William Thomson, have hereunto set my hand and seal, this Nineteenth day of August, in the year of our Lord One thousand eight hundred and fifty-eight.

WILLIAM THOMSON. (L.S.)

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THOMSON'S SPECIFICATION.

(1 SHEET)

Figure. 1.

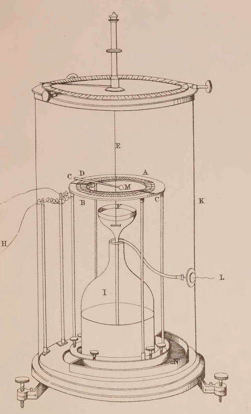


Figure. 2.

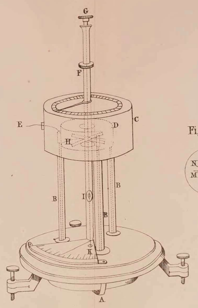


Figure. 3.

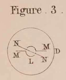
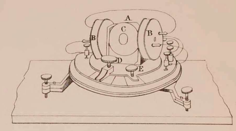


Figure. 6.



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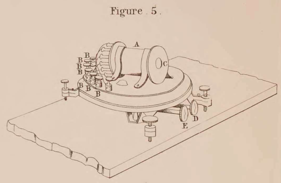
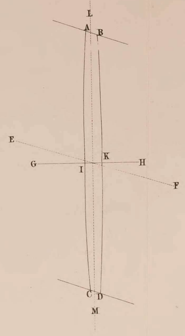


Figure. 4.

Figure. 7.



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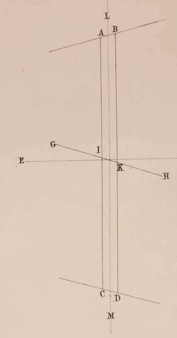
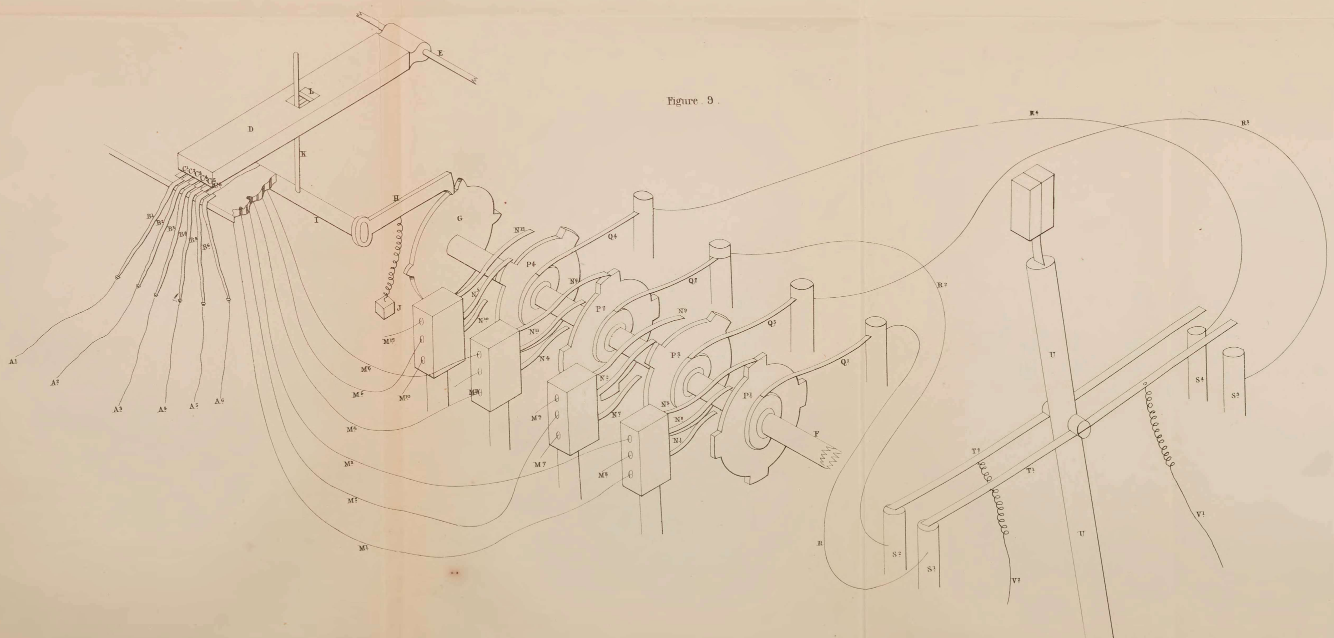


Figure. 9.



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